the distilled water were full of Bacteria, the others remaining barren. This was done to show that the liquid, although deprived of its power of germination, is as capable as before of supporting the life of Bacteria.

The results of the preceding experiments may be summed up as follows:—In sixteen experiments the liquids were subjected to the temperature of boiling at the normal pressure; of these, eight were heated for 15 minutes, and all bred Bacteria; six were heated for 30 minutes, of which two bred Bacteria; two for an hour, both of which were barren.

Of ten subjected to the temperature of ebullition at pressures not exceeding one inch, eight were barren. Both the liquids which were found to be pregnant had been heated for 30 minutes, one under a pressure of one-tenth of an inch, the other of one inch.

In the twelve experiments in which the liquids were heated under pressures exceeding one inch, all were barren, although half of them were subjected to that temperature for only 15 minutes.

It is unnecessary for me to draw any inferences from the preceding experiments; it may not, however, be superfluous to point out that, although all the flasks heated above 101° C. remained sterile, this fact affords no ground for concluding that any definite relation exists between that precise temperature and the destruction of the germinating power of the liquid in question. All that has been shown is that the *chance* that such a liquid will breed Bacteria is diminished either by slightly increasing the temperature to which it is heated, or increasing the duration of the heating. Thus it appears to me quite probable that if a sufficiently large number of flasks were heated even to 102° C., some of them would still be found to be pregnant.

University Coll., London, June 7 J. Burdon Sanderson

Fertilisation of the Pansy.—Ground Ivy

There is one further point in the structure of *Viola tricolor* which is not mentioned by Mr. Bennett or by Mr. Hart, but which seems to confirm the theory of the former gentleman that *V. tricolor*, as distinguished from most other Violas, is fertilised by a small insect such as Thrips instead of by the proboscis of larger insects.

Before I saw Mr. Bennett's paper, my attention had been called by Miss Dowson to the fact that whereas in the Sweet and Dog Violets, the circle of anthers presses close to the style all round, there is in *V. tricolor* an opening between the two appendaged stamens. The use of this opening will evidently be to allow the small creature to enter in and crawl down the stamen to the nectary at the end of the appendage. This structure may be also seen in *V. cornuta*, which seems to be fertilised in the same way. In *V. tricolor* the opening is exactly opposite to the black streak, or guide-post, as Mr. Bennett has termed it. In *V. cornuta*, although this black mark is not so evident, there is a distinct triangular mark pointing downwards exposed by the opening of the stamens. On each side of the style are two sets of hairs, looking like "whiskers" to the scull-like crest of the style, on which lots of pollen rest. The small insect on entering the flower can hardly help crawling into the cavity at the top of the stigma, for the entrance to the flower is almost completely blocked up by it. On emerging from it it would crawl over the top, which Mr. Hart mentions as seen in *tricolor*, and which I also find in *cornuta*, be guided through the hole by the triangular mark, and so find his way to the nectary. On emerging, covered with pollen, and entering its next flower, it will again be deluded into the *cul-de-sac* in which the stigmatic surface is, where it will deposit its pollen. The details of the structure of the appendaged stamens, as contrasted with those of other Violas, fully bear out this view.

As regards the English translation for the German *bestäuben*, I would suggest to Mr. Hart that "pollenate" is an impossible word; *pollen, pollinis*, must give the verb to "pollinate," as *fulmen, fulminis* gives *fulminate*. But there is a great advantage in a word which speaks for itself, and, if the word "be-pollen" offends scientific ears (Mr. Hart does not tell us why), would the literal translation of the German "to be-dust" be offensive? If not, I think it would tell its own tale. The word "empollen" seems justified by *embalm*, but the prefix generally means to place in or convert into, as in *enthral, emprison, embed*. Hence it would at least be ambiguous.

The form of Ground Ivy mentioned by your correspondent S.S.D. grows here abundantly in several spots, seeds freely, and is remarkable for having a much shorter style in proportion to the tube of the corolla than the common form in which the style and stigmas protrude from the tube. F. E. Kitchener

Rugby, June 15

Mr. Kitchener having been kind enough to send me the above letter, I may, perhaps, be allowed to add a few additional notes. Since writing the former paper I have had the opportunity of examining three other species of *Viola, V. calcarata, elatior*, and *lactea*, all of which present a remarkable contrast to *V. tricolor* in a very curious point of structure. In *V. tricolor* the stigma is brought into close contact with the lowest petal by a very peculiar "knee" in the style, the effect of which is so completely to close up the central cavity of the flower as to render it extremely difficult for any large insect to insert its proboscis into the spur. In all the three species above-named, which I believe to be fertilised by bees, the style is nearly straight, so as to leave a considerable gap between the stigma and lower petal, quite large enough for the insertion of the proboscis of a bee. In none of these is there the least indication of the black triangular streak on the style which I take to serve, in *V. tricolor*, the purpose of guiding the Thrips to the nectary. The ring of anthers is also perfectly closed, as described by Miss Dowson in the case of the Dog and Sweet Violet, there being no opening for the admission of the small insect, as in the pansy. A striking difference in the form of the stigma also favours the same conclusion as to the mode of fertilisation.

Alfred W. Bennett

*ON THE ORIGIN AND METAMORPHOSES OF INSECTS**

VI.

The metamorphoses of insects have always seemed to me one of the greatest difficulties of the Darwinian theory. In most cases, the development of the individual reproduces to a certain extent that of the race; but the motionless, imbecile pupa cannot represent a mature form. No one, so far as I know, has yet attempted to explain, in accordance with Mr. Darwin's views, a life history, such as that of a butterfly, in which the mouth is first mandibulate and then suctorial. A clue to the difficulty may, I think, be found in the distinction between developmental and adaptive changes; to which I have called attention in a previous article. The larvæ of insects are by no means mere stages in the development of the perfect animal. On the contrary, they are subject to the influence of natural selection, and undergo changes which have reference entirely to their own requirements and condition. It is evident, then, that while the embryonic development of an animal in the egg may be an epitome of its specific history, this is by no means the case with species in which the immature forms have a separate and independent existence. If an animal when young pursues one mode of life, and lives on one kind of food, which subsequently, either from its own growth in size and strength, or from any change of season, alters its habits or food, however slightly, it immediately becomes subject to the action of new forces: natural selection affects it in two different and, it may be, very distinct manners, gradually leading to differences which may become so great as to involve an intermediate period of change and quiescence.

There are, however, peculiar difficulties in those cases in which, as among the Lepidoptera, the same species is mandibulate as a larva, and suctorial as an imago. From this point of view *Campodea* and the Collembola (*Podura*, &c.) are peculiarly interesting. There are among insects three principal types of mouth—first, the mandibulate; secondly, the suctorial; and thirdly, that of *Campodea* and the Collembola generally, in which the mandibles and maxillæ are retracted, but, though far from strong, have some freedom of motion, and can be used for biting and chewing soft substances. This type is intermediate between the other two. Assuming that certain representatives of such a type found themselves in circumstances which made a suctorial mouth advantageous, those individuals would be favoured by natural selection in which the mandibles and maxillæ were best calculated to pierce or prick, and their power of lateral motion would tend to fall into abeyance; while, on the other hand, if powerful masticatory jaws were an advantage, the opposite process would take place.

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* Continued from p. 109.

There is yet a third possibility—namely, that during the first portion of life, the power of mastication should be an advantage, and during the second that of suction, or *vice versâ*. A certain kind of food might abound at one season and fail at another, might be suitable for the animal at one age and not at another: now in such cases we should have two forces acting successively on each individual, and tending to modify the organisation of the mouth in different directions. It will not be denied that the ten thousand variations in the mouth-parts of insects have special reference to the mode of life, and are of some advantage to the species in which they occur. Hence no believer in natural selection can doubt the possibility of the three cases above suggested, the last of which seems to explain the possible origin of species which are mandibulate in one period of life and not in another. The change from the one condition to the other would no doubt take place contemporaneously with a change of skin. At such times we know that, even when there is no change to form, the temporary softness of the organs precludes the insect from feeding for a time, as, for instance, is the case with the silkworm. When, however, any considerable change was involved, this period of fasting would be prolonged, and would lead to the existence of a third condition, that of the pupa, intermediate between the other two. Since other changes are more conspicuous than those relating to the mouth, we are apt to associate the existence of a pupa-state with the acquisition of wings: but the case of the Orthoptera (grasshoppers, &c.) is sufficient proof that the development of wings is perfectly compatible with continuous activity; so that in reality the necessity for rest is much more intimately connected with the change in the constitution of the mouth, although in many cases no doubt the result is accompanied by changes in the legs, and in the internal organisation. An originally mandibulate mouth, however, like that of a beetle, could not, I think, be modified into a suctorial organ like that of a bug or a gnat, because the intermediate stages would necessarily be injurious. Neither, on the other hand, for the same reasons, could the mouth of the Hemiptera be modified into a mandibulate type like that of the Coleoptera. But in *Campodea* and the Collembola we have a type of animal closely resembling certain larvæ which occur both in the mandibulate and suctorial series of insects, and possessing a mouth neither distinctly mandibulate, nor distinctly suctorial, but constituted on a peculiar type capable of modification in either direction by gradual change, without loss of utility.

In discussing this subject it is necessary also to take into consideration the nature and origin of wings. Whence are they derived? why are there normally two pairs? and why are they attached to the meso- and metathorax? These questions are not less difficult than interesting. It has been suggested, and I think with justice, that the wings of insects originally served for aquatic and respiratory purposes. From the various modes by which respiration is effected among the different groups of aquatic insects, there are strong reasons for concluding that the original insect stock was, like *Campodea* (Pl 3, Fig. 5), a land animal. But in aquatic insects there is a tendency to effect the purification of the air through the delicate membraneous covering of more or less leaf-like expansions of the skin. In the larva of *Chloëon* (Pl. 4, Fig. 1), for instance, that singularly resembles *Campodea* (Pl. 3, Fig. 5), several of the segments are provided with such foliaceous expansions; which, moreover, are in constant agitation, the muscles of which, in several remarkable points, resemble those of the true wings. It is true that in *Chloëon* the vibration of the so-called branchiæ is scarcely, if at all, utilised for the purpose of locomotion; the branchiæ are, in fact, placed too far back to act efficiently. The situation of these branchiæ differs in different groups; indeed, it seems probable that originally there were a pair on each segment. In such a case, those branchiæ, situated near the centre of the body, neither too much in front nor too far back, would serve the most efficiently as propellers. The same causes which determined the position of the legs would affect the wings also. Thus a division of labour would be effected; the branchiæ on the posterior segments of the thorax would be devoted to locomotion; those on the abdomen to respiration. This would tend to increase the development of the thoracic segments, already somewhat enlarged to receive the muscles of the legs.

That wings may be of use to insects under water is proved by the very interesting case of *Polynema natans*, which I discovered in 1862, and which uses its wings to swim with. This, however, is a rare case; and it is possible that the principal use of the wings was, primordially, to enable the mature forms to pass from pond to pond, thus securing fresh habitats and avoiding in-and-in breeding. If so, the development of wings would tend to be relegated to a late period of life; and by the tendency to the inheritance of characters at corresponding ages, to which Mr. Darwin has called attention,[*] the development of wings would be associated with the maturity of the insect. Thus the late acquisition of wings in the Insecta generally, seems to be itself an indication of their descent from a stock which was at one period aquatic in its habits, and which probably resembled the present larvæ of *Chloëon* in form, but had thoracic as well as abdominal branchiæ.

If these views are correct, the genus *Campodea* must be regarded as a form of remarkable interest, since it is the living representative of a primæval type from which not only the Collembola and Thysanura, but the other great orders of insects have all derived their origin.

Finally, from the subject of metamorphoses we pass naturally to that most remarkable phenomenon which is known as the "Alternation of Generations:" for the first systematic view of which we are indebted to my eminent friend Prof. Steenstrup.

I have always felt it very difficult to understand why any species should have been created in this double character; nor, so far as I am aware, has any explanation of the fact yet been attempted. Yet insects offer, in the metamorphoses which they go through, a phenomenon not altogether dissimilar, and give a clue to the manner in which alternation of generations may have originated.

The caterpillar owes its difference from the butterfly to the early stage at which it leaves the egg; but its actual form is mainly due to the influence of the conditions in which it lives. If the caterpillar, instead of changing into one butterfly, produced several butterflies, we should have an instance of alternation of generations. Until lately, however, we knew of no such case; each larva produced one imago, and that not by generation but by development. It has long been known, indeed, that there are some species in which certain individuals remain always apterous, while others acquire wings. Many entomologists, however, regard these abnormal individuals as perfect, though wingless insects; and therefore, though these cases appear to me to deserve more attention than they have yet received, I shall not found any argument on them.

Recently, however, Prof. Wagner of Kazan, has discovered that, among certain small gnats, the larvæ do not themselves directly produce the perfect insect, but give rise to other larvæ, which undergo metamorphoses of the usual character, and eventually become gnats. His observations have been confirmed, as regards this main fact, by other naturalists; and there can, I think, be no doubt that they are, in the main, correct.

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[*] Origin of Species, 4th ed. pp. 14 and 97.

Here, then, we have a distinct case of alternation of generations, as characterised by Steenstrup. Probably other cases will be discovered in which insects undeniably in the larval state will be found to be fertile. Nay, it seems to me possible, if not probable, that some larvæ which do not now breed, in the course of ages may come to do so.

If this idea is correct, it shows how the remarkable phenomenon known as alternation of generations may have originated. At any rate, we find among insects every mode of development; from simple growth on the one hand, to well-marked alternation on the other. In the wingless species of Orthoptera there is little difference, excepting in size, between the young larva and the perfect insect. The growth is as simple and gradual as in any other animal; and the creature goes through nothing which would, in ordinary language, be called a metamorphosis. In the majority of Orthoptera the presence of wings produces a marked difference between the larva and the imago. The habits, however, are nearly the same throughout life, and consequently the action of external circumstances affects the larva in the same manner as the perfect insect.

This is not the case with the Ephemeridæ. The larvæ do not live under the same conditions as the perfect insects; external forces accordingly affect them in a different manner; and we have seen that they pass through some changes which bear no reference to the form of the perfect insect: these changes, however, are for the most part very gradual. The caterpillars of Lepidoptera have even more extensive changes to undergo; the mouth of the larva, for instance, is remarkably unlike that of the perfect insect. A change in this organ, however, could hardly take place while the insect was still growing fast, and consequently feeding voraciously. Nor, even if the change could be thus effected, would the mouth, in its intermediate stages, be in any way fitted for biting and chewing leaves. The same reasoning applies also to the digestive organs. Hence the caterpillar undergoes little, if any, change, except in size, and the metamorphosis is concentrated, so to say, into the last two moults. The changes then become so rapid and extensive, that the intermediate period is necessarily one of quiescence.

Owing to the fact that the organs connected with the reproduction of the species come to maturity at a late period, larvæ are generally incapable of breeding. There are, however, some flies which have viviparous larvæ, and thus offer a typical case of alternation of generations, owing to the early period of leaving the egg, and the action in many cases of external circumstances on the larva different from those which affect the mature form.

Thus, then, we find among insects every gradation, from the case of simple growth to that of alternation of generations; and we see how from the single fact of the early period at which certain animals quit the egg, we can account for their metamorphoses and for the still more remarkable phenomenon that, among many of the lower animals, the species is represented by two very different forms. We may even, from the same considerations, see reason to conclude that this phenomenon may in the course of ages become still more common than it is at present. As long, however, as the external organs arrive at their mature form before the internal generative organs are fully developed, we have cases of metamorphosis; but if the reverse is the case, then alternation of generations often results.

The same considerations throw much light on the remarkable fact, that in alternation of generations the reproduction is, as a general rule, agamic in the one form. This results from the fact that reproduction by distinct sexes requires the perfection both of the external and internal organs; and if the phenomenon arise, as has just been suggested, from the fact that the internal organs arrive at maturity before the external ones, reproduction will result in those species only which have the power of agamic multiplication.

Moreover it is evident that we have in the animal kingdom two kinds of dimorphism.

This term has usually been applied to those cases in which animals or plants present themselves at maturity under two different forms. The different forms of ants and bees afford us familiar instances among animals; and among plants the remarkable case of the genus *Primula* has recently been worked out with his usual ability by Mr. Darwin. Even more recently he has made known to us the still more remarkable phenomenon afforded by the genus *Linum*, in which there are three distinct forms, and which therefore offers an instance of polymorphism.[*]

The other kind of dimorphism or polymorphism differs from the first in resulting from the differentiating action of external circumstances, not on the mature, but on the young individual. The different forms, therefore, stand towards one another in a relation of succession. In the first case the chain of being divides at the extremity; in the other it is composed of dissimilar links. Many cases of dimorphism under this second form have been described under the name of alternation of generations.

The term, however, has met with much opposition, and is clearly inapplicable to the differences exhibited by insects in different periods of their life. Strictly speaking the phenomena are very frequently not alternate, and, in the opinion of many eminent naturalists, they are not cases of generation at all.[†]

In order, then, to have some name for these remarkable phenomena, and to distinguish them from those cases in which the *mature* animal or plant is represented by two or more different forms, I think it would be convenient to retain for these latter exclusively the terms dimorphism and polymorphism; and those cases in which animals or plants pass through a succession of different forms might be distinguished by the name of dieidism or polyeidism.

The conclusions, then, which I think we may draw from the preceding and other considerations are:—

1. That the occurrence of metamorphoses arises from the immaturity of the condition in which some animals quit the egg.

2. That the form of the insect larva whenever it departs from the original vermiform type, depends in great measure on the conditions in which it lives. The external forces acting upon it are different from those which affect the mature form; and thus changes are produced in the young which have reference to its immediate wants, rather than to its final form.

3. That metamorphoses may therefore be divided into two kinds, developmental and adaptational.

4. The apparent abruptness of the changes which insects undergo arises in great measure from the hardness of their skin, which admits no gradual alteration of form, and which is itself necessary in order to afford sufficient support to the muscles.

5. The immobility of the pupa or chrysalis depends on the rapidity of the changes going on in it.

6. Although the majority of insects go through three well-marked stages after leaving the egg, still a large number arrive at maturity through a somewhat indefinite number of slight changes.

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[*] Of course all animals in which the sexes are distinct are in one sense dimorphic.

[†] "There is no such thing as a true case of 'alternation of generations in the animal kingdom; there is only an alternation of true generation with the totally distinct process of gemmation or fission."—*Huxley on Animal Individuality*, Ann. and Mag. of Nat. Hist., June 1852.

7. When the external organs arrive at this final form before the organs of reproduction are matured, these changes are known as metamorphoses; when, on the contrary, the organs of reproduction are functionally perfect before the external organs, or when the creature has the power of budding, then the phenomenon is known as alternation of generations.

8. Thus, then, it appears probable that these remarkable phenomena may have arisen from the simple circumstance that certain animals leave the egg at a very early stage of development, and that the external forces acting on the young are different from those which affect the mature animal.

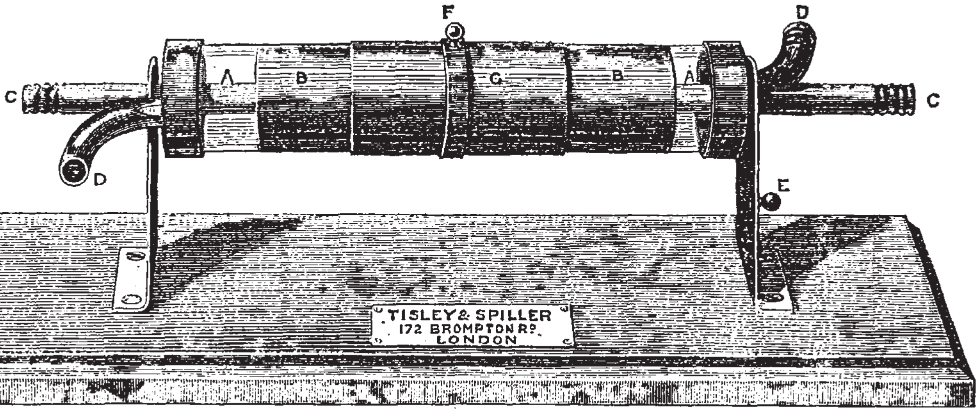
JOHN LUBBOCK

(*To be continued.*)

ON AN IMPROVED FORM OF OZONE GENERATOR

A SHORT description of an improved form of ozone generator, exhibited at the last meeting of the Chemical Society, may perhaps be interesting to the readers of NATURE.

Probably no apparatus hitherto introduced, for the production of ozone by electric induction, has in its working given universal satisfaction. The original form of "Siemens' tube" has many disadvantages, amongst which the chief are, the extremely fragile nature of the two glass tubes, especially when sealed together by the blowpipe, and the fact that if the apparatus be worked for any length of time it becomes heated, thereby causing a diminution in the quantity of ozone obtained. The arrangement of a number of glass plates coated on alternate sides with tin foil, and enclosed in a box, known as "Beane's" instrument, possesses—especially if used as it is intended it should be with a large and powerful coil—this latter disadvantage to a considerable extent. Sir Benjamin Brodie, during his researches upon ozone, used a modification of "Siemens' tube," which in a great degree overcame this difficulty. Two glass tubes closed at one end, and of such diameter that one was capable of sliding within the other, were fixed together in that way, the junction being effected either by the blowpipe or by means of paraffin, thus leaving a small annular space between them through which the oxygen or other gas to be ozonised could circulate; tin foil coatings were dispensed with altogether, the inner tube being filled with water, and the whole apparatus stood in a vessel of water, wires in conection with an induction coil being placed in the interior tube, and also in the outer vessel: this water could be kept cool by ice, and thus any heat produced during the time it was in use was successfully neutralised. Such an apparatus works exceedingly well but requires delicate handling, and is not perhaps very well adapted for having other pieces of apparatus attached to it.



New Ozone Generator.

This new instrument is an improved modification of the above, but permits of a continuous stream of water of any required temperature being maintained through it; and further, the annular space which in the case of glass tubes is often very irregular, causing thereby an unequal electrical discharge, is made as true as possible, and the result is a more uniform conversion of the gas into ozone. The apparatus as at present made will be better understood by the following description referring to the accompanying diagram:—A A is a piece of glass tube of a little more than one inch in diameter, and of as uniform a bore as can be obtained. On each end of this tube is placed a brass cap, bored with two holes, and coated internally with shellac; in the interior of this glass tube and of a diameter scarcely less than that of the tube itself, but not quite so long, is placed a thin hollow brass box, B B, with its surface made as true as possible by turning in a lathe; this brass box is placed concentrically with the outer tube and is completely coated on its exterior surface with tin, the tin being acted upon to the smallest extent by the ozone. This hollow box communicates with the exterior of the apparatus by means of the tubes C C passing through the centre of the caps. It is intended that a current of water shall be kept circulating through the interior of this box, the water being brought into direct contact with its sides by means of a small spiral placed within it, the box being of a slightly less diameter than the glass tube, a small annular space will remain between the two, and through this space the gas to be ozonised is passed by means of the tubes D D; the box itself is made one of the electrified surfaces, and a strip of tin foil G, fixed to the outside of the glass tube, forms the other; two binding screws, E and F, serve to make the necessary connections with an induction coil.

The production of ozone by this apparatus is exceedingly regular and constant. No quantitative estimations with iodide of potassium and sulphurous acid have as yet been made with regard to the amount of ozone obtained, but an approximate experiment upon the quantity of indigo bleached in a given time, seems to indicate that this amount is quite equal to, if not rather in excess of, that obtained when the ordinary apparatus is used. This instrument possesses also some minor advantages; it is not so easily broken, other pieces of apparatus are very readily attached to it, and at the same time its cost is less. There appears to be no reason why larger forms should not be manufactured upon the same principle. These instruments are made by Messrs. Tisley and Spiller of Brompton.

THOS. WILLS